SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Engineering.

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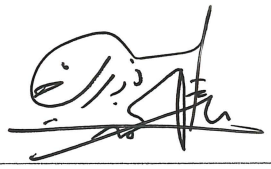
I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.



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DEVELOPMENT OF A COMPUTER VISION-BASED TECHNIQUE FOR ANALYSIS OF HAND THERAPY EXERCISE

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ABSTRAK

Senaman terapi tangan berdasarkan sistem penglihatan komputer mempunyai banyak manfaat dan telah menarik minat para penyelidik ke arah membangunkan aplikasi penglihatan komputer. Inovasi alat pengukuran untuk senaman telah mengalami penambahbaikan yang berterusan hingga ke hari ini, di mana sebahagiannya menggunakan *"wearable sensor"*, bantuan robot dan penglihatan komputer. Sistem yang telah dibina menggunakan kaedah penglihatan komputer melibatkan struktur badan manusia yang fleksibel dan mennyebabkan *"self-occlusion"*. Masalah lain ialah teknik pengesanan menggunakan kamera biasa yang tidak mudah dan memerlukan masa untuk dibangunkan. Tujuan penyelidikan ini adalah untuk membangunkan teknik berasaskan penglihatan komputer untuk menganalisis senaman terapi tangan dan untuk menilai pengukuran sudut yang telah dicadangkan dengan alat pengukuran konvensional, iaitu goniometer. Dalam tesis ini, senaman Latihan Bergerak (*Range of Motion (ROM)*) untuk pergelangan tangan dan siku dengan menggunakan sensor Kinect dibentangkan dan senaman ini memberikan maklum balas dalam masa nyata untuk setiap pergerakan. Kedua-dua senaman, iaitu pergelangan tangan *"radial/ulnar"* dan lenturan siku *"flexion/extension"* adalah terdiri daripada pengukuran sudut pada sendi. Algoritma yang digunakan adalah pengesanan dan penjejakkan tangan, pengesanan hujung jari, pengesanan sendi rangka dan juga algoritma pengukuran sudut pada sendi. Kemudian, nilai-nilai sudut sendi boleh disimpan secara automatik. Hasil keputusan bagi pengukuran sudut sisihan pergelangan tangan *"radial/ulnar"* menunjukkan perbezaan daripada sudut rujukan sebanyak ±6°. Manakala, hasil bagi pengukuran sudut sendi siku *"flexion/extension"* adalah sebanyak ±8° dari sudut rujukan. Nilai-nilai ukuran hampir sama dengan nilai-nilai rujukan piawai ROM iaitu 20° untuk *"radial"*, -30° untuk *"ulnar"*, 140° untuk *"flexion"* dan 0° untuk *"extension"*. Algoritma telah berjalan dengan baik dan boleh mengikuti pergerakan pada masa nyata. Sistem senaman menggunakan sensor Kinect mampu menjadi alat latihan yang mudah alih, mudah untuk dipasang dan diletakkan di mana-mana. Data pengukuran sudut boleh disimpan dan boleh digunakan untuk rujukan pada masa hadapan. Pengesahan dengan alat konvensional dalam pengukuran sudut menunjukkan bahawa ukuran sudut adalah lebih tepat berbanding goniometer kerana ia boleh mengukur skala yang lebih kecil.

ABSTRACT

Hand therapy exercises based on computer vision system have many benefits and this has attracted the interest of researchers towards building a computer vision application. The innovation of measurement tool in computer vision application for the exercise also have undergone continuously improvement which is using wearable sensor, robot aid and computer vision. The hand therapy exercise system that was built using computer vision method involved highly flexible structure of the human body and causes a self-occlusion. Another problem is tracking techniques using an ordinary camera are not easy and require extensive time to develop. The aim of this research is to develop a computer vision-based technique for analysis of hand therapy exercise and to evaluate the propose angle measurement with the conventional measurement tool, which is goniometer. In this thesis a Range of Motion (ROM) exercises for wrist and elbow by using the Kinect sensor is presented and this exercise provides a real-time feedback for every movement. Both exercises, which are wrist radial/ulnar deviation and elbow flexion/extension also consists of joint angle measurement. For this purpose, the ROM exercise was developed by using the hand detection and tracking, fingertips detection, skeleton joints detection algorithms and joint angle measurement algorithm. Then, the joint angle values can be saved automatically. The result for the measurement of wrist radial/ulnar deviation angle shows its value is different from the reference angle of ±6°. Meanwhile, the result for the measurement of elbow flexion/extension joint angle was different at ±8° from the reference angle. These measurement values are almost similar to the standard ROM reference values which are 20° for radial deviation, -30° for ulnar deviation, 140° for flexion and 0° for extension. The algorithm worked well and could follow the movement of the upper arm and forearm in real-time. This exercise system that uses Kinect sensor is able to be a portable exercise tool, which is easy to install and to be placed anywhere. The joint angle measurement data can be saved and can be used for reference in the future. The validation with the conventional tool for angle measurement (goniometer) shows that the joint angle measurement with the proposed technique is more precise compared to the goniometer because it can measure the small scale of angle in degree.

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LIST OF SYMBOLS

m	Metre
mm	Millimetres
cm	Centimetre
s	Seconds
ms	Milliseconds
°	Degree
sf	Scaling Factor
P_1	Frame Pixel, x and y coordinate
P_2	Frame Pixel, x and y coordinate
P_{1new}	Frame Pixel, x and y coordinate
P_{2new}	Frame Pixel, x and y coordinate
dz	Distance from Kinect sensor to hand detection
T_{Z1}	Threshold value of hand depth
T_{Z2}	Threshold value of hand depth
D_{pij}	Distance between two point of hand contour
P_j	Hand contour point
P_i	Hand contour point
C	Hand contour
H	Convex hull
R	Radius of the maximum inscribed circle
θ	Theta
$P1_{(x,y)}$	Reference palm point
$H_{(x,y)}$	Detection palm point
V_1	Vector of hand
V_2	Vector of hand

LIST OF ABBREVIATIONS

3D	Three Dimensions
API	Application Programming Interfaces
CSV	comma separated values
CTS	Carpal Tunnel Syndrome
FES	Functional Electrical Stimulation
fps	Frame per seconds
GUI	Graphical User Interface
IR	Infrared
MIRA	Medical Interactive Recovery Assistant
OS	Operating System
ROI	Region of Interest
ROM	Range of Motion

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